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Magnetic stray field based position detection in outer rotor permanent magnet synchronous machines

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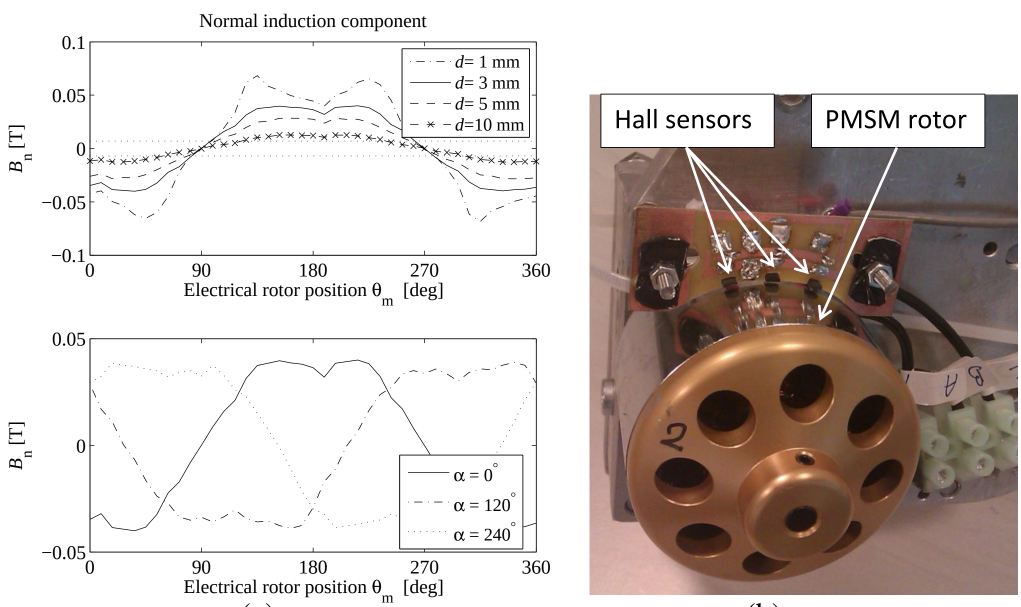
The stray field of electrical machines can be used for fault monitoring (H. Henao, C. Demian, and G-A. Capolino, “A frequency-domain detection of stator winding faults in induction machine using an external flux sensor”, IEEE Trans. Ind. Appl., Vol. 39 No. 5, 2003). However, in an outer rotor permanent magnet synchronous machine (PMSM), the stray field can also be used to detect the rotor position. We prove that the accuracy of position detection is sufficient to implement a brushless DC control with position information given by three Hall sensors in the stray field of the machine. Putting the sensors outside the machine is an advantage in electric vehicle wheel motors: the Hall sensors are not exposed to the high temperatures of the motor, they don’t increase the shaft length, and they require no additional bearings.

The stray field computation of an outer rotor PMSM can be done by 2D FEM in the $r-\phi$-plane, if the sensor is located close to the rotor surface and at an axial position z near the middle of the machine. Otherwise, 3D computations are required. To avoid full 3D simulations, homogenization techniques are given in literature (V. P. Bui, O. Chadebec, L-L. Rouve, et al., “Analysis of the stray magnetic field created by faulty electrical machines”, in COMPEL, Vol. 27, pp. 224-234, 2008).

The focus of the research is on the optimal position of the sensors in order to provide accurate position information. By using 2D and 3D models, the effect of the position and orientation of the sensors on the output signal is shown. Furthermore, the effect of the stator current is studied: high stator currents slightly shift the switching points of the Hall-sensors, and make the position information less accurate. The effect of the rotor temperature cannot be neglected although the sensors themselves are not heated as well: the remanent magnet flux decreases with temperature, causing lower magnetic induction in the stray field around the machine. When using Hall sensors SS411A that are guaranteed to switch between -7 and 7 mT, Figure 1 shows that the distance between the Hall-sensor and the rotor yoke can be up to 10 mm, still being sure that the sensors will switch correctly.



(a) (b)

Figure 1: (a) Normal (radial) component of the magnetic induction as a function of the radial distance d from the outer surface of the rotor yoke, and as a function of the circumferential position angle α. The dotted lines show the trigger level of the Hall sensors; (b) Picture of the Hall sensors outside the PMSM.